NASA TN D-223

7N-18
198489
19P

TECHNICAL NOTE
D-223

EFFECTS OF NOSE CORNER RADII, AFTERBODY SECTION DEFLECTIONS, AND A DROGUE CHUTE ON SUBSONIC MOTIONS OF MANNED-SATELLITE MODELS IN REENTRY CONFIGURATION

By Willard S. Blanchard, Jr., and Sherwood Hoffman

Langley Research Center
Langley Field, Va.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

WASHINGTON March 1960

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

TECHNICAL NOTE D-223

EFFECTS OF NOSE CORNER RADII, AFTERBODY SECTION DEFLECTIONS, AND A DROGUE CHUTE ON SUBSONIC MOTIONS OF MANNED-SATELLITE MODELS IN REENTRY CONFIGURATION

By Willard S. Blanchard, Jr., and Sherwood Hoffman

SUMMARY

Models of manned satellites in the reentry configuration were tested to determine the effect of nose corner radii, afterbody section deflections, and a drogue chute on the motions in free flight at subsonic speeds. The mass characteristics of the models were similar to those of a full-scale manned satellite. The tests were conducted in the Langley 20-foot free-spinning tunnel.

When tested with various nose corner radii, the basic body exhibited amplitudes of steady-state oscillations that varied from approximately $\pm 45^{\circ}$ with sharp nose corners to about $\pm 60^{\circ}$ with the larger nose corner radii. Large reductions in the amplitudes of the oscillations resulted when a drogue chute was added or when the afterbody segments were deflected. The models with large corner radii and opened afterbody had virtually no residual oscillations.

INTRODUCTION

Much interest has been directed toward the solution of problems associated with putting a man in orbit about the earth and bringing him safely back. One of these problems is the stabilization of the vehicle in the reentry configuration. In particular, blunt-nose low-fineness-ratio bodies have poor damping and tend to oscillate through large angles at subsonic speeds. The present investigation was initiated by the Langley Pilotless Aircraft Research Division to explore various ways of reducing or eliminating these oscillations.

The tests reported herein were made to investigate the effects of various nose corner radii, afterbody section deflections, and a drogue chute on the subsonic motions of an orbital vehicle, or capsule, in the reentry configuration. The basic shape consisted of a blunt nose and conical afterbody which were joined at a sharp corner. The rear half of the afterbody was first divided into three equal sections and then four equal sections for the tests. These sections were pivoted about hinges in the afterbody so that the deflection angles could be varied.

The tests were conducted in the Langley 20-foot free-spinning tunnel at a Reynolds number of about 400,000 per foot, at low subsonic speeds. The center-of-gravity location of the full-scale manned satellite was duplicated on the model, and the mass characteristics, with an assumed full-scale maximum diameter of 7 feet, corresponded to a full-scale weight and pitch moment of inertia of about 2,600 pounds and 500 slugs-ft^2, respectively.

L
7
9
4

SYMBOLS

l_a length of afterbody, 10.54 in.

r_c nose corner radius, in.

θ amplitude of oscillation, measured from flight path to axis of symmetry, deg

δ deflection angle of opened afterbody section, deg

MODELS

Figures 1 to 4 are drawings showing the geometry of the configurations tested. Figure 1 shows the basic body, which consisted of a truncated cone having a $14\frac{1}{2}^\circ$ half-angle. The maximum diameter was 7 inches. The small end of the basic body was spherical in shape, with a 1-inch radius, and was faired smoothly into the truncated cone. The basic nose was a portion of a sphere having a 10.5-inch radius. The resulting intersection between the nose and the conical body was approximately 90°.

Figure 2 shows a comparison of the basic configuration with the five other noses tested. Nose corner radii were varied from zero ($r_c/l_a = 0$ for the basic nose) to 2 inches ($r_c/l_a = 0.19$). For all the models except the basic configuration, the corner radius was tangent to the afterbody surface and to a flat face as is shown in figure 2.

Figure 3 shows the drogue chute tested. The chute was 7 inches in diameter in the laid-out-flat position and was sufficiently porous to be stable. The distance from the top of the chute to the apex of the shroud lines was about 8 inches, and the chute was attached to a single point on the center line of the capsule by a towline 12 inches long.

Figure 4 shows a typical configuration with opened afterbody. Tests were made with three- and four-section afterbodies and afterbody section deflections δ of 30°, 45°, and 60°. The sections were made by dividing longitudinally the rear 48 percent of the afterbody into three equal parts and four equal parts.

All the models were constructed of balsa wood and plastic and were ballasted to give a center-of-gravity location at 1.43 inches rearward of the nose and afterbody juncture. Each model weighed approximately $1\frac{1}{2}$ pounds and had a pitch moment of inertia of about 0.002 slug-ft^2. These mass characteristics correspond to a weight of about 2,600 pounds and a pitch moment of inertia of about 500 slugs-ft^2 for a full-scale reentry configuration which would have a maximum diameter of about 7 feet.

TESTS

The tests reported herein were made in free flight in the Langley 20-foot free-spinning tunnel. This tunnel and its operation are described in reference 1. Tunnel speeds were varied from about 50 feet per second for the tests with a drogue chute to about 70 feet per second for the satellite alone in order to balance drag against weight. The corresponding Reynolds numbers were 320,000 and 440,000 per foot. As an example, in terms of full-scale flight, the average Reynolds number would correspond to a velocity of about 100 feet per second at an altitude of 17,000 feet. Free-stream static pressure was about 15 pounds per square inch.

Each configuration was launched by hand several times in order to vary the initial conditions. It was found that the resultant steady-state oscillation for each configuration was independent of whether the model was launched smoothly or at a high rate of pitch.

RESULTS AND DISCUSSION

The model motions were recorded on motion-picture film at about 60 frames per second, and values of θ were determined by analysis of the film. Sequence photographs of representative tests of the model with closed afterbody without and with the drogue chute are presented in figures 5(a) and 5(b), respectively. The amplitude of the oscillations was smaller with the drogue chute deployed.

Figure 6 shows several representative sequences of tests to determine the effect of opened afterbody on the amplitude of the oscillation of the body with various nose corner radii. Models having either three-segment or four-segment afterbodies with segment deflections of 30°, 45°, and 60° exhibited reduced oscillation amplitudes, as compared with the afterbody-closed configurations.

Amplitudes of the steady-state oscillations are shown in figure 7 for all the models tested. Figure 7(a) shows the effect of the drogue chute on the amplitudes for the various nose corner radii. The drogue chute caused a decrease in amplitude from about $\pm 45^{\circ}$ to about $\pm 30^{\circ}$ for L
the sharp-cornered nose ($r_c/l_a = 0$). Increasing the nose corner radius 7
resulted in increased oscillation amplitudes for the body alone and in 9
decreased oscillation amplitudes for the model with the drogue chute. 4
For the largest nose corner radius tested ($r_c/l_a = 0.19$), the drogue chute caused a decrease in amplitude from about $\pm 60^{\circ}$ to about $\pm 20^{\circ}$. Since these tests were conducted primarily to determine the effects of corner radius, no attempt was made to determine the effects of chute size and towline length on the oscillations.

Figure 7(b) shows the effect of afterbody section deflections on the oscillations of the basic body. Deflections of 30°, 45°, and 60° for the three and four segments of the afterbody caused oscillations of amplitudes within the shaded portion of the figure. No systematic variation in oscillation amplitude was noted for the various afterbody segment deflections (30°, 45°, or 60°) nor for the number of segments (three or four). However, as seen in figure 7(b), the opened afterbody caused a decrease in amplitude of oscillation as compared with the closed afterbody for all corner radii tested. The average reduction in amplitude varied from about 10° for the sharp-cornered nose ($r_c/l_a = 0$) to about 60° for the largest nose corner radius ($r_c/l_a = 0.19$). For nose corner radii between $r_c/l_a = 0.095$ and $r_c/l_a = 0.14$, there is apparently a critical nose-corner-radius effect. The results also indicate that the configurations with corner radii greater than $r_c/l_a = 0.14$ and opened afterbody are either fully damped or oscillate at amplitudes less than $\pm 2^{\circ}$. (See fig. 6(b).) It should be noted, however, that the test Reynolds numbers were very low (about 400,000 per foot) and that the aforementioned observations may not apply at higher Reynolds numbers (refs. 2 and 3). Nevertheless, there is a significant regime of flight for a possible full-scale manned satellite in which an escape maneuver would cause the satellite to pass through the Reynolds number range of these tests wherein Mach number effects should be negligible.

CONCLUDING REMARKS

An investigation has been made to determine the effects of nose corner radii, afterbody section deflections, and a drogue chute on the subsonic motions of manned-satellite models in the reentry configuration. The basic body, tested with various nose corner radii, exhibited amplitudes of steady-state oscillations that varied from about $\pm 45^{\circ}$ with the sharp cornered nose to approximately $\pm 60^{\circ}$ with the larger nose corner radii. The addition of a drogue chute or afterbody section deflections caused large reductions in the amplitude of the oscillations. The models with large corner radii and opened afterbody had virtually no residual oscillations.

Langley Research Center,
National Aeronautics and Space Administration,
Langley Field, Va., November 5, 1959.

REFERENCES

1. Neihouse, Anshal I., Klinar, Walter J., and Scher, Stanley H.: Status of Spin Research for Recent Airplane Designs. NACA RM L57F12, 1957.

2. Lichtenstein, Jacob H., Fisher, Lewis R., Scher, Stanley H., and Lawrence, George F.: Some Static, Oscillatory, and Free-Body Tests of Blunt Bodies at Low Subsonic Speeds. NASA MEMO 2-22-59L, 1959.

3. Polhamus, Edward C.: Effect of Flow Incidence and Reynolds Number on Low-Speed Aerodynamic Characteristics of Several Noncircular Cylinders With Applications to Directional Stability and Spinning. NASA TR R-29, 1959. (Supersedes NACA TN 4176.)

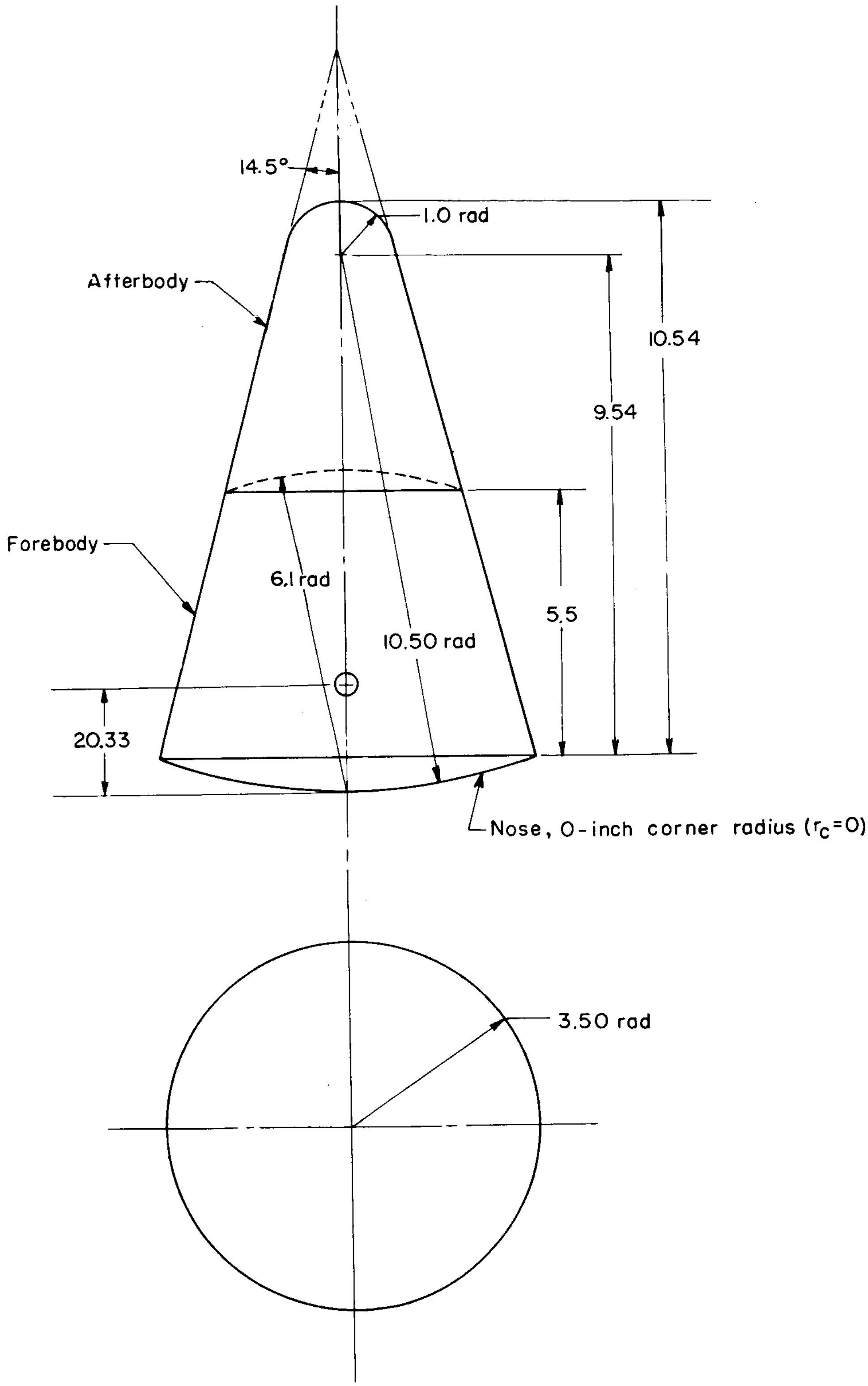


Figure 1.- Details and dimensions of model with the nose having 0-inch corner radius. All dimensions are in inches.

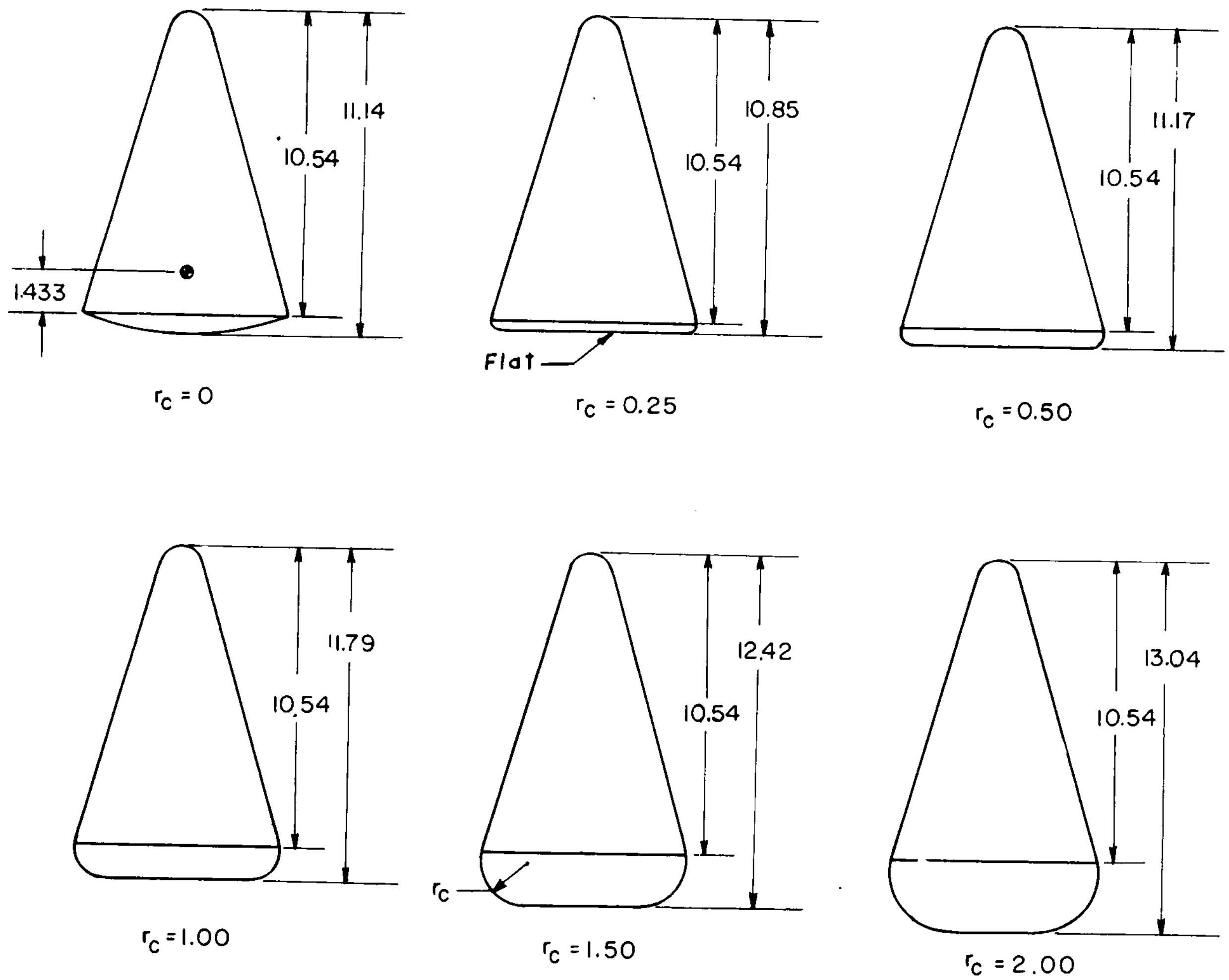


Figure 2.- Configurations tested with various nose shapes and closed afterbody. All dimensions are in inches.

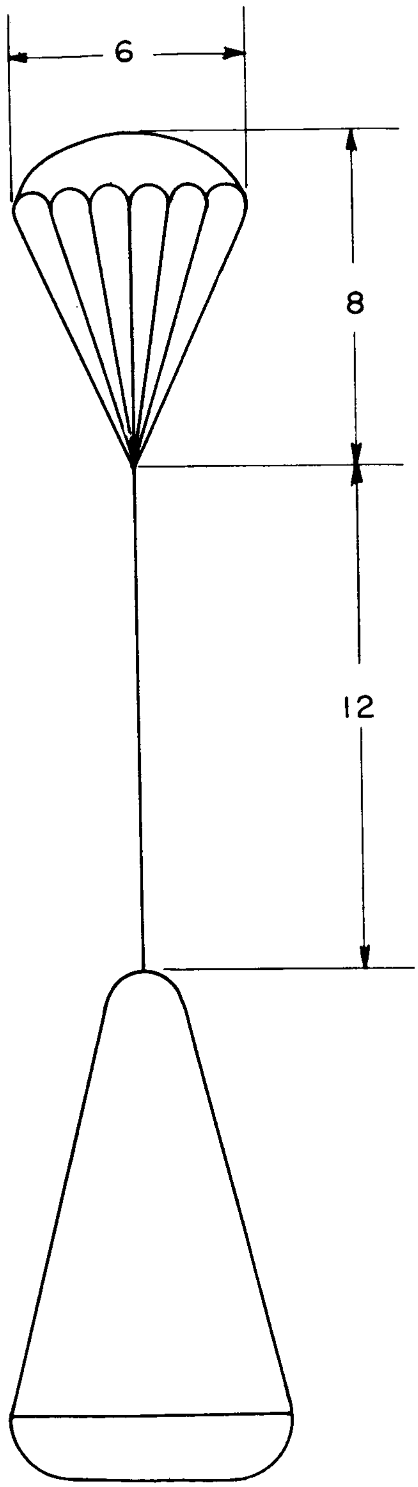


Figure 3.- Drogue chute on a typical model with closed afterbody. All dimensions are in inches.

L-794

N

L-794

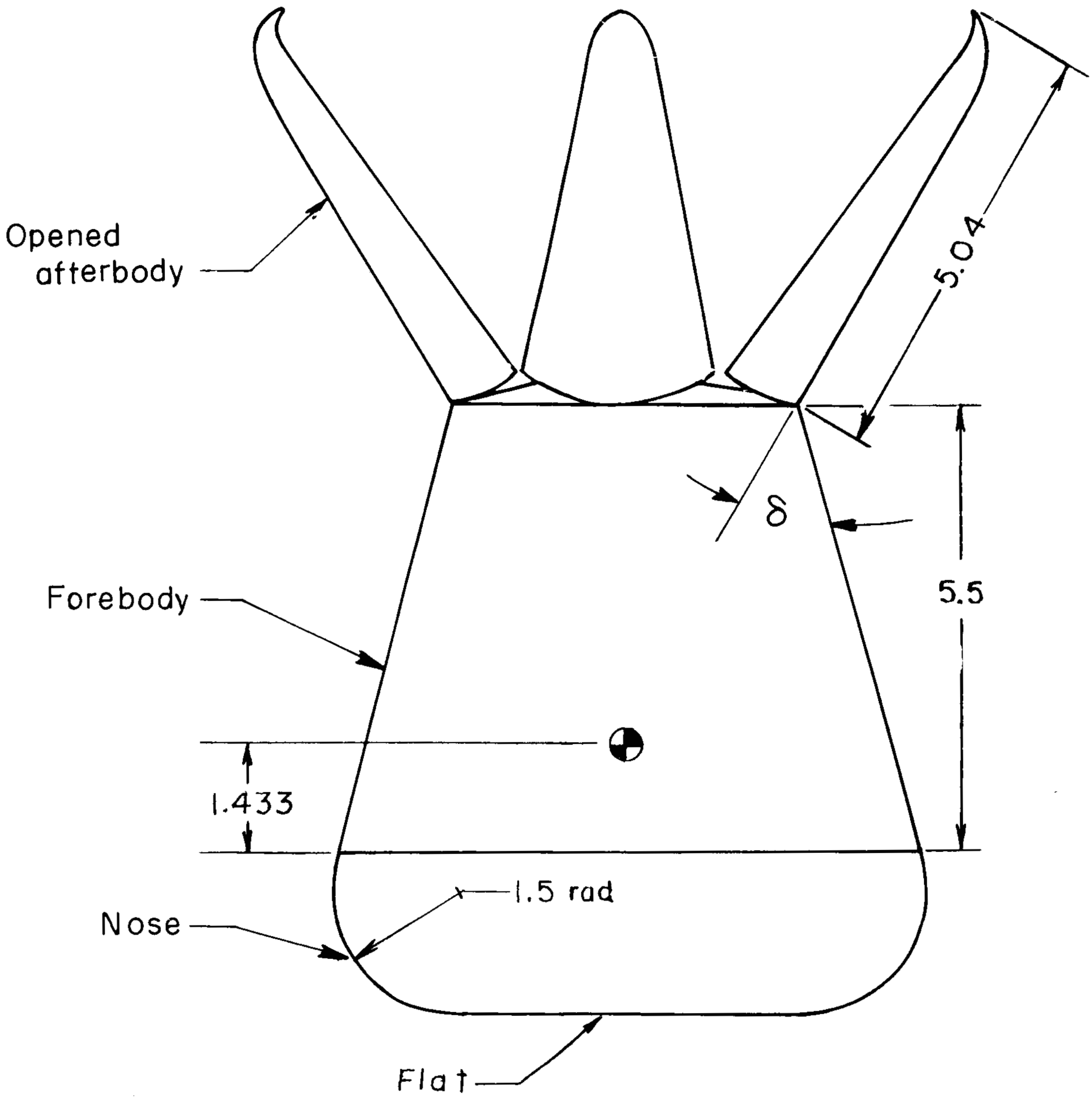
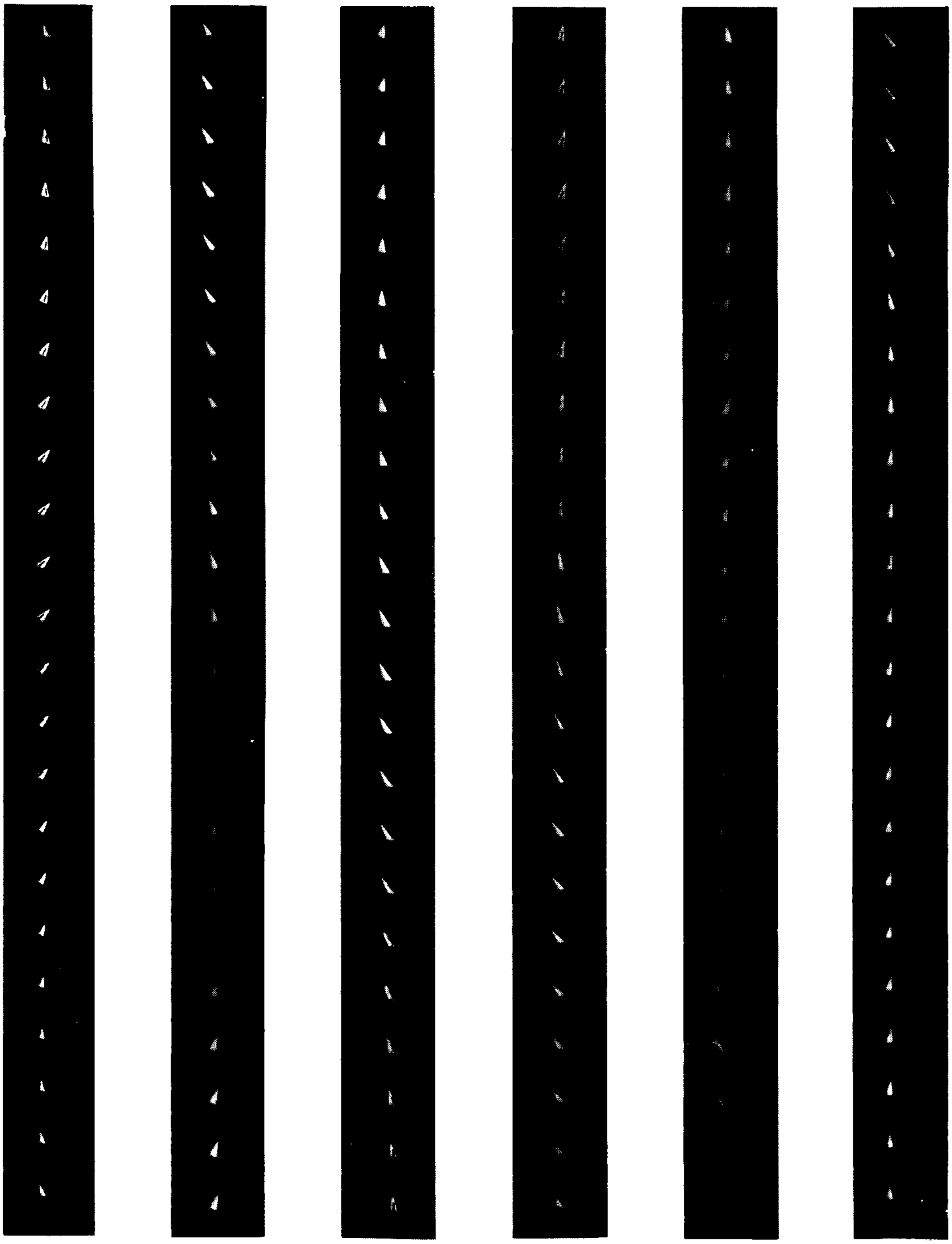


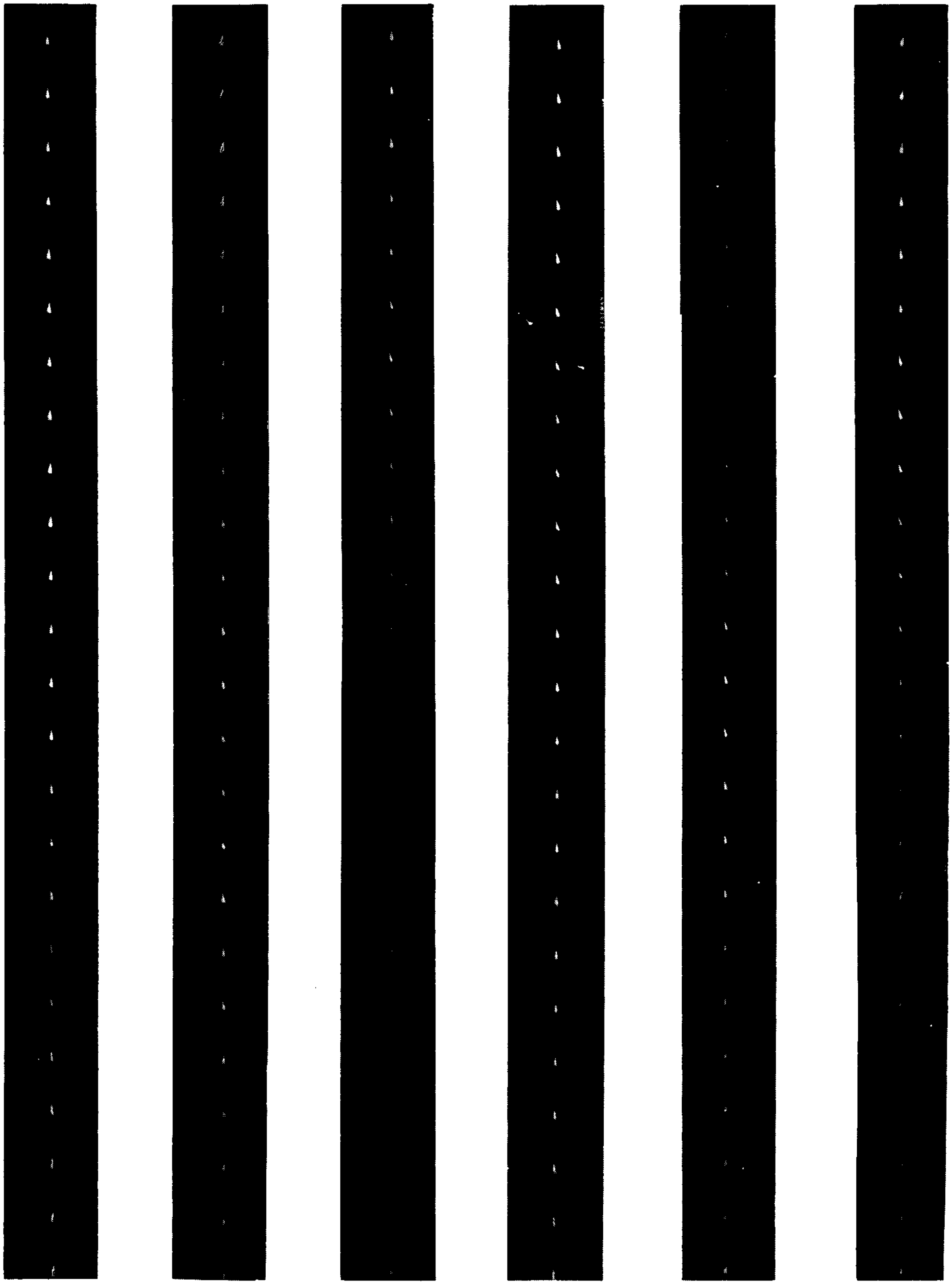
Figure 4.- Typical configuration with afterbody opened in four sections and nose with 1.5-inch corner radius. All dimensions are in inches.



(a) $r_c = 1.5$. L-59-6474

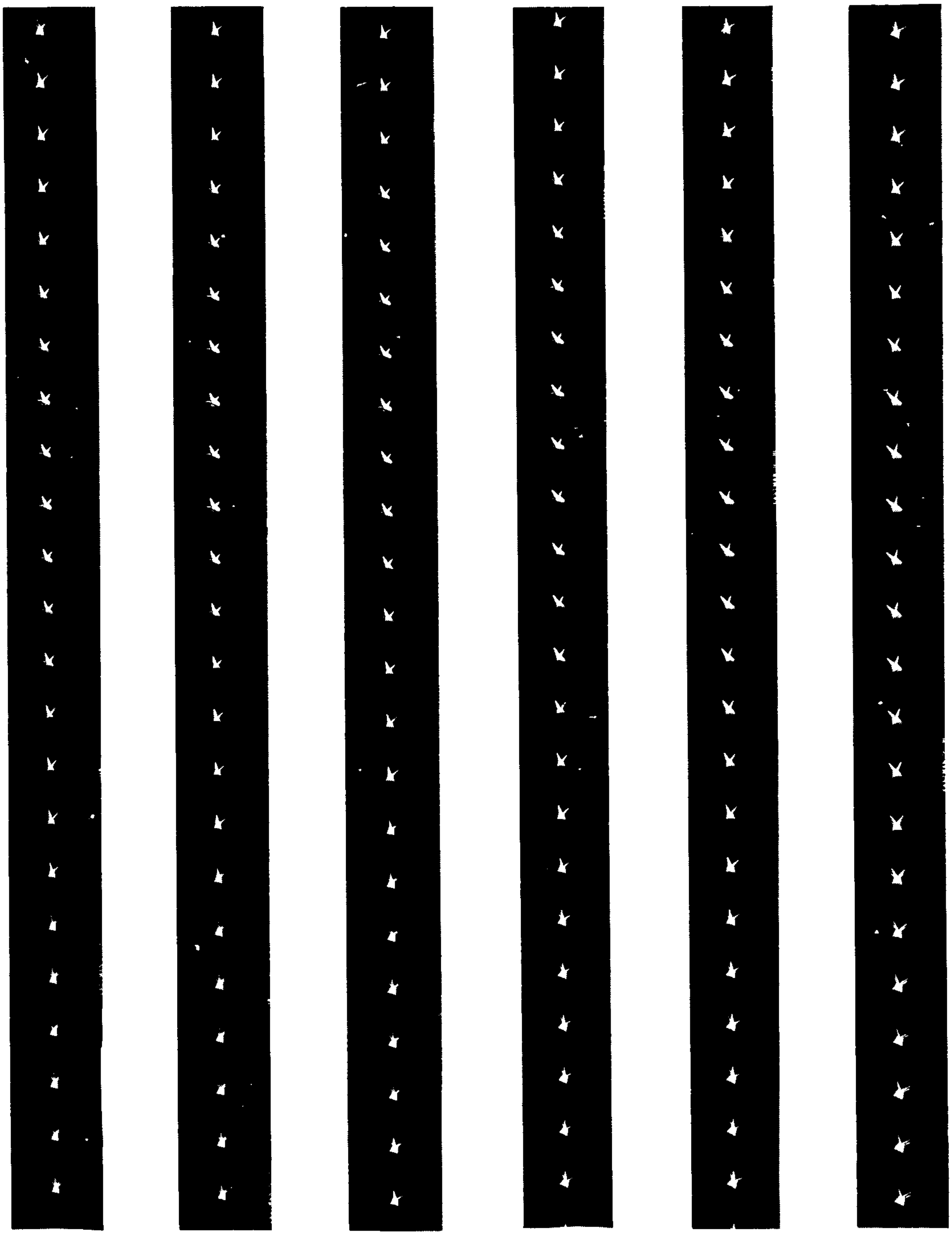
Figure 5.- Sequence photographs of two of the tests with closed afterbody.

L-794



(b) $r_c = 1.5$ and drogue chute. L-59-6475

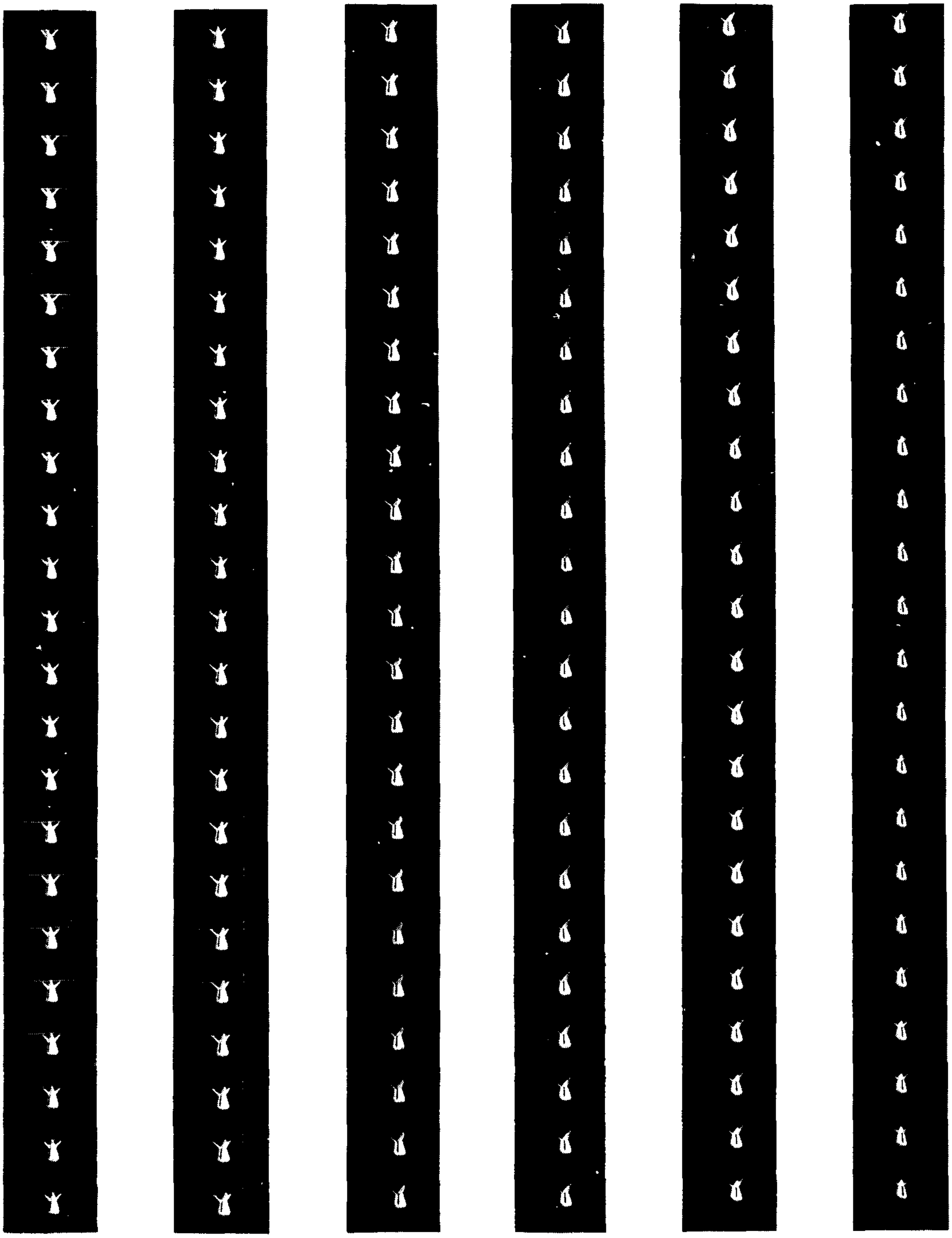
Figure 5.- Concluded.



(a) $r_c = 0$; $\delta = 60^\circ$; four segments. L-59-6476

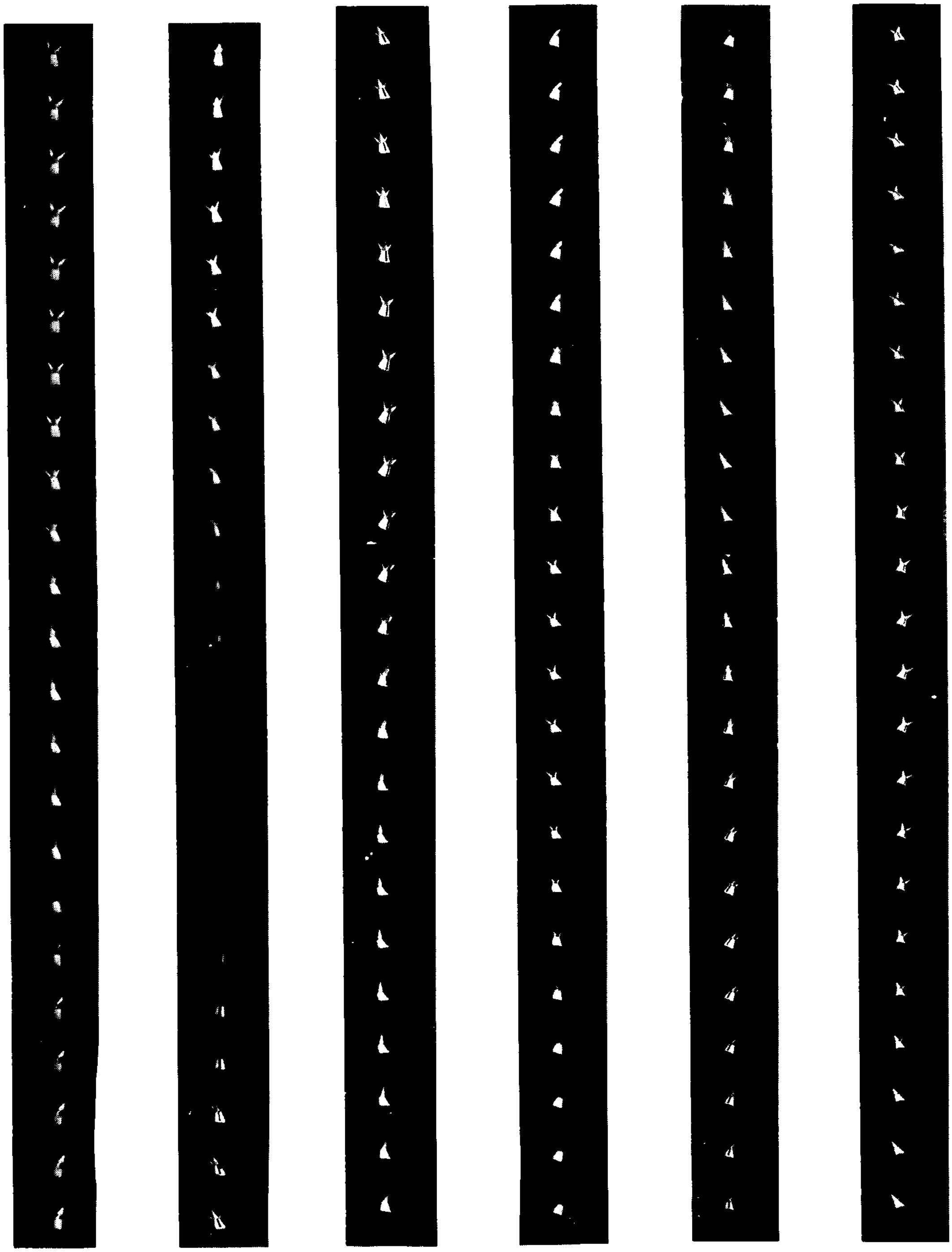
Figure 6.- Sequence photographs of several of the tests with opened afterbody.

L-794



(b) $r_c = 2.0$; $\delta = 60^\circ$; three segments. L-59-6477

Figure 6.- Continued.

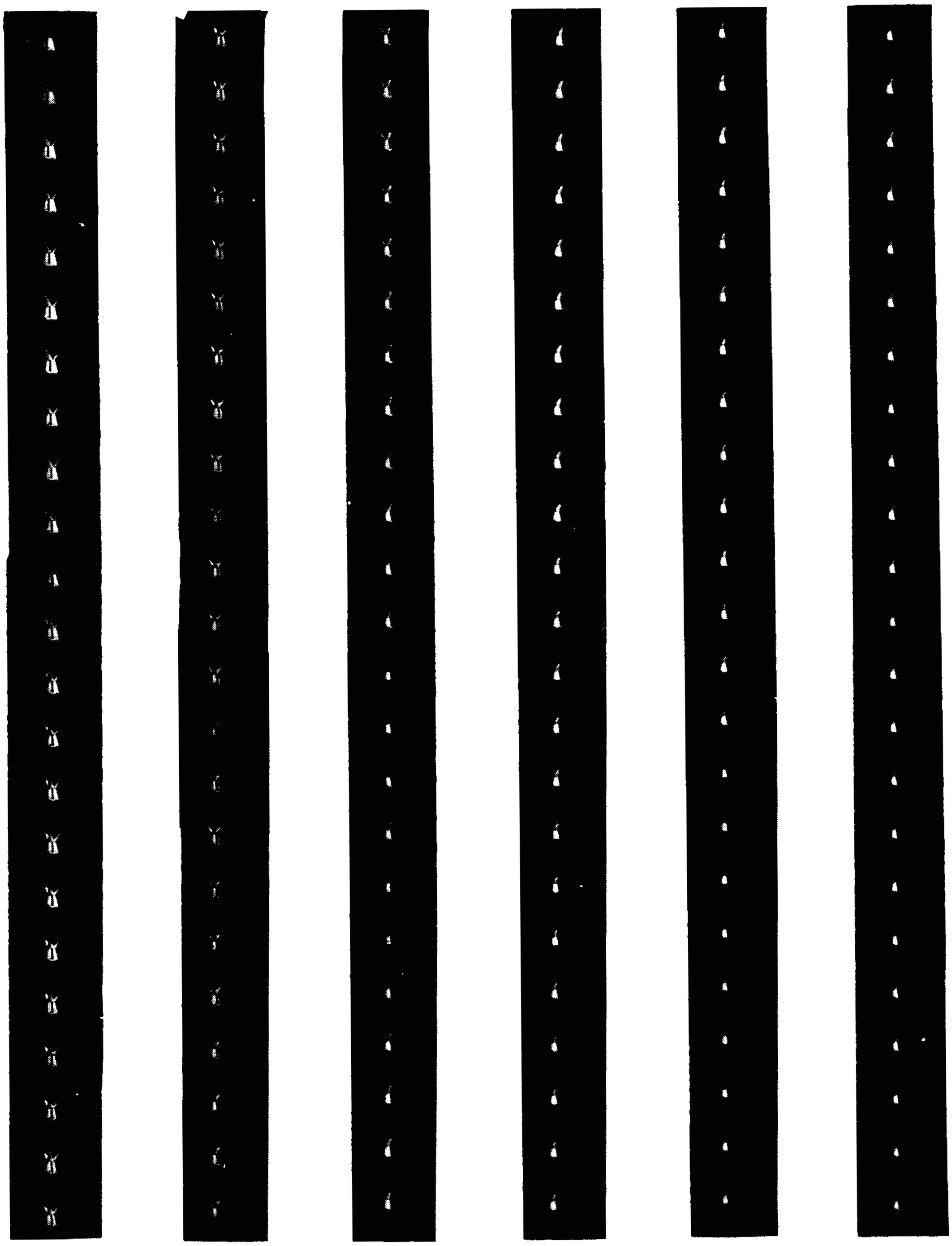


(c) $r_c = 1.0$; $\delta = 45^{\circ}$; three segments. L-59-6478

Figure 6.- Continued.

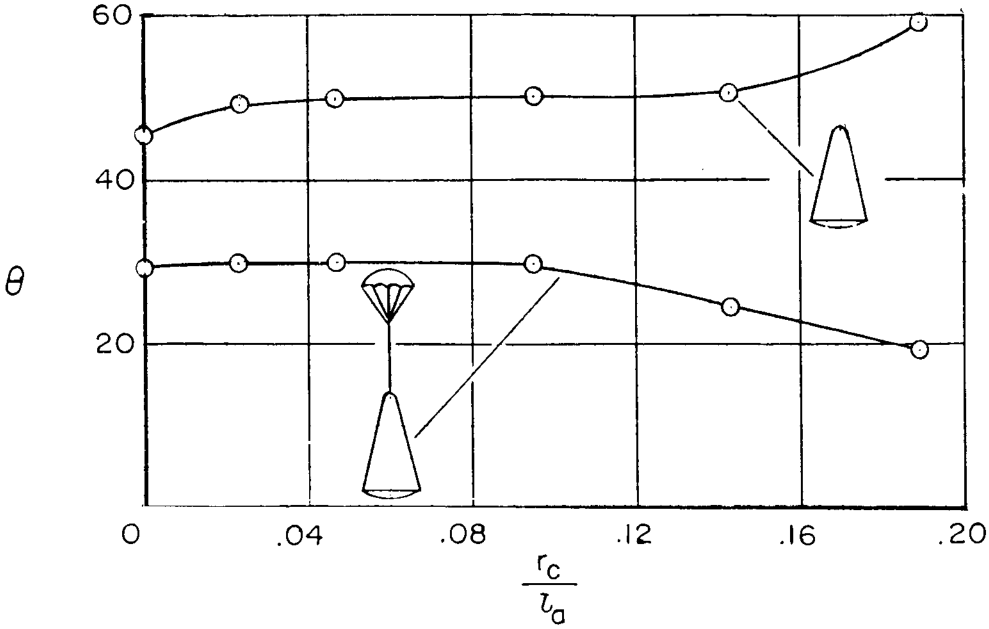
L-794

L-794

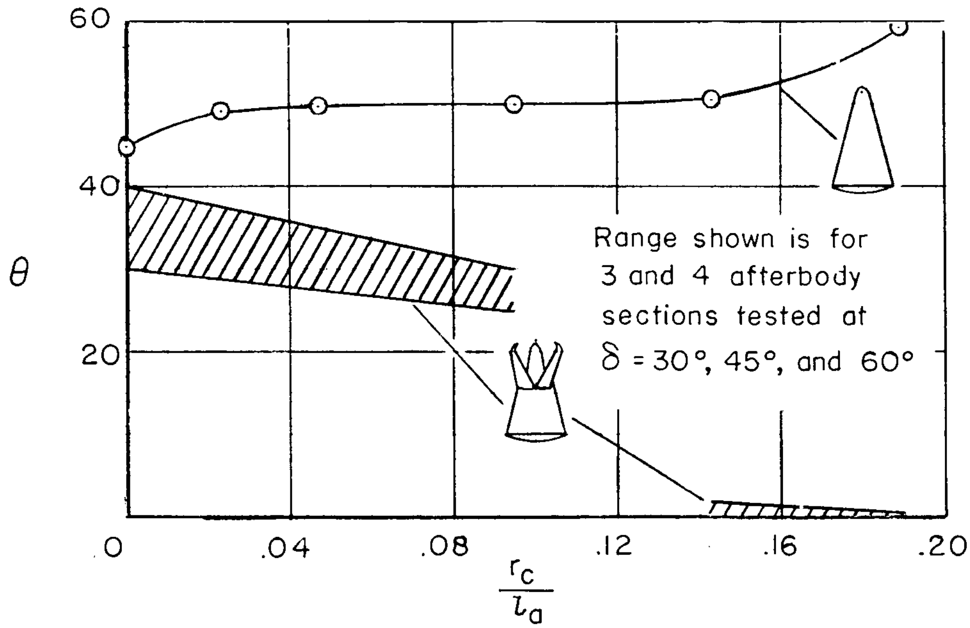


(d) $r_c = 1.5$; $\delta = 45^\circ$; three segments. L-59-6479

Figure 6.- Concluded.



(a) Effect of drogue chute.



(b) Effect of opened afterbody.

Figure 7.- Effect of drogue chute and open afterbody on the amplitude of oscillation of the model.

NASA - Langley Field, Va. L-794